

## MICROFLUIDIC CONNECTION

### **1. Field of the Invention**

[0001] The present invention relates to a microfluidic connection.

5      **2. Discussion of the Background Art**

[0002] chemical analysis microfluidic devices are becoming increasingly important. The so-called lap-on-chip technology allows to perform chemical reactions and chemical analysis on microscopic scale using very small compound volumes. Microfluidic devices minimize the time and costs  
10 associated with biological and chemical analysis and will improve reproducibility. Furthermore, multiple experiments can be performed on a single small chip. Due to the small size only a few tenths of nanoliters up to a few microliters of different compounds are used, resulting in a faster and more accurate reaction. The paper by F.Eckhardt et al., "MUSE, Lap-on-  
15 Chip for Chemical Analysis In-Situ" found at:  
"https://escies.org/public/mnt4/S4.2Eckhard.pdf" gives an overview about different analysis methods using a lap-on-chip technology.

[0003] Figure 3 of the paper shows a typical microfluidic device used for chemical analysis including microfluidic channels connected to inlet areas  
20 for injecting the fluids.

[0004] While chemical analysis or even chemical reactions can be performed in microfluidic channels or reactors respectively, one might connect microfluidic devices together or a microfluidic device to a macrofluidic device and inject the fluids into the microfluidic channels. It is  
25 an object of this invention to provide an improved microfluidic connection.

**SUMMARY OF THE INVENTION**

[0005] According to an embodiment of the invention the microfluidic connection comprises a carrier element adopted to have a microfluidic channel. A carrier element is fixed between a feeding element and a backplate, the feeding element comprising a channel adopted for feeding a fluid into the microfluidic channel of the carrier element. The fixing of the carrier element having the microfluidic channel between the feeding element and the backplate allows the fluid to be pressed into the microfluidic channel using very high pressure. The use of very high pressures up to 400,000 hPa (400bar) might be necessary, since the volume of the microfluidic channels is very small, thus resulting in a very high friction between the channel walls and the fluid.

[0006] The expression microfluidic device or microfluidic channel defines or describes respectively a device having dimension not achievable by conventional processing methods like drilling, boring, milling eroding or the like. A microfluidic channel might not be structured by mechanical means but by different processes involving light. Such processes include laser ablating or different etching methods. The dimension of such channels can vary in the range of 10µm or less up to approximately 100µm. Channels, holes structured by mechanical means are considered a macrofluidic devices.

[0007] The backplate represents a pressure imposing element compensating the filling pressure of the fluid and protecting the connection between the macrofluidic channel of the feeding element and the microfluidic channel of the carrier element from damage and especially from bursting. In one embodiment of the invention the channel of the feeding element comprise a microfluidic channel. In this embodiment the invention forms a tight, high pressure stable connection between two microfluidic channels. Such connection can be used to inject a fluid into a microfluidic

reactor. In an alternate embodiment of the invention, the channel of the feeding element is structured to form a macrofluidic channel, thereby connecting the microfluidic channel.

- [0008] In a further embodiment of the invention the carrier element 5 comprises at least a first and a second layer, wherein at least the first or the second layer is structured to form a microfluidic channel. This structure can be etched or ablated by a laser-induced process.

- [0009] In a further embodiment the carrier element, and preferably the 10 first layer, comprises an opening on a first side adopted for feeding a fluid from the feeding element into the microfluidic channel. The opening is arranged below the feeding element. The dimension of the channel head of the feeding element has approximately the same value as the dimension of the opening in the first layer. In yet another embodiment the diameters are different. Such a structure will result in a relatively big opening 15 compared to the dimension of the microfluidic channel.

- [00010] In a further embodiment of the invention the backplate is arranged on a second side of the carrier element at least partly upholding the feeding element. The fluid feeding pressure acting upon the layer of the carrier elements are compensated by the back pressure of the backplate. 20 [00011] In a further embodiment of the invention the backplate is connected to the feeding element by a screw connection. This will allow a backplate and the feeding element to be pressed tightly together thereby fixing the opening of the microfluidic channel. Alternately the microfluidic channel comprises a clamping element for pressing the feeding element 25 and the backplate together.

[00012] In a further embodiment of the invention the backplate comprises a recess filled by an elastic thrust piece. The elastic thrust piece results in a dynamic back pressure depending on the feeding pressure of the fluid. It

further represents a safety device for protecting the connection against overpressure of the fluid. In an embodiment of this invention the feeding element comprises a second microfluidic channel arranged next to the first microfluidic channel and connected to a small microfluidic volume in the  
5 carrier element. The small microfluidic volume is arranged over the elastic thrust piece and disconnected from the microfluidic channel by a valve . Exceeding the feeding pressure of fluid will result in an overpressure of the elastic thrust piece thereby opening the valve between the microfluidic channel and the microfluidic volume, thereby reducing the overpressure. In  
10 an embodiment of this invention a small wall is formed between the microfluidic channel and the microfluidic volume adopted to form the valve.

[00013] In a further embodiment the elastic thrust piece comprises at least one of the following materials: Teflon, polyurethane, PEEK, or elastomers. Alternately the elastic thrust piece comprises a spring arranged  
15 in the recess.

[00014] The backplate as well as the feeding element might comprise steel or tantalum or titan or PEEK respectively. The carrier element can comprise a first and a second layer formed by polyimides or PEEK foils. In an embodiment the thickness of the carrier element is approximately 300  
20  $\mu\text{m}$  but can be less or more than this. The microfluidic channel comprises a thickness of approximately 50  $\mu\text{m}$ . Alternately the thickness of the carrier element is in the range of about 100  $\mu\text{m}$  to 1000 $\mu\text{m}$ , while the dimension of the microfluidic channel is in the range of 10  $\mu\text{m}$  to 100 $\mu\text{m}$ . The thickness of the carrier element can even be greater, if more different layers are used.  
25 In this embodiment of the invention the microfluidic connection is adopted for withstanding fluid feeding pressures up to 400 bar.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[00015] Other objects and many of the attendant advantages of the embodiment of the present invention will be readily appreciated and better understood by reference to the following description of preferred 5 embodiments. The embodiments are presented in connection with the accompanying drawings. The drawings referenced herein are used for illustration purposes only. It will be apparent to those skilled in the art that those drawings do not limit the scope of the invention. Features, that are substantially or functionally equal or similar will be referred to with the same 10 reference signs.

[00016] Figure 1 shows a cross-sectional side view of a first embodiment of the present invention.

[00017] Figure 2 shows the top view of the carrier element according to the first embodiment.

15 [00018] Figure 3 shows a cross-sectional side view of a second embodiment of the present invention.

[00019] Figure 4 shows a cross-sectional side view of a third embodiment of the present invention.

20 [00020] Figure 5 shows an explosion side view of a fourth embodiment of the present invention.

[00021] Figure 6 shows the cross-sectional side view of the fourth embodiment of the present invention.

[00022] Figure 7 shows a cross-sectional side view of a fifth embodiment of the present invention.

25 [00023] Figure 8 shows a top view of a carrier element having a microfluidic spraying nozzle.

[00024] Figure 9 shows a cross-sectional side view of a sixth embodiment of the present invention.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

- 5 [00025] Figure 1 shows a first embodiment of the present invention of a carrier element comprising a microfluidic channel fixed between a feeding element and a backplate. The carrier element 3 comprises a first layer 32 having an opening 35 and a second layer 33. The first layer 35 is arranged onto the second layer 33. The second layer 33 is structured to form a  
10 microfluidic channel. The microfluidic channel, for example, can be structured by etching into the surface of the second layer 33. Alternatively the structure of the microfluidic channel can also be ablated from the surface of the layer 33 by a laser-induced process. The etching and the ablation method as well as similar structuring processes will result in a small  
15 recess in layer 33, having a depth of roughly 5µm-50 µm. On this second structured layer the first layer 32 comprising the opening 35 is arranged. The first layer 32 is glued onto the second layer. The opening 35 is placed directly above a structured microfluidic channel in the layer 33. A fluid can be injected into the microfluidic channel via the opening 35.
- 20 [00026] Structuring a microfluidic channel in the carrier element 3 according to this embodiment of the invention is also described in detail in application EP 1 350 759, which is incorporated herein by reference. On top of layer 32 and the hole 35 the feeding element 1 is arranged. The feeding element 1 comprises a tube 16 , whose walls 11 are shown in Figure 1. The tube represents a macrofluidic channel with a channel head placed directly  
25 over the opening 35 of the second layer 32 of the carrier element 3.

[00027] The tube 16 with its walls 11 is made of steel or tantalum or fused silica or similar material, capable of withstanding high pressures. The

diameter of the tube 16 is approximately 10 times bigger than the opening 35 of the carrier element 3. A fastening device 13 is welded or bonded or similar, but tightly connected onto the tube's walls 11. The fastening device 13 comprises at least two bore holes 14 through the metal of the fastening device 13 on each side of the tube 16. The bore holes 14 are formed as housings for screws 15, which are used to connect the backplate 2 with the feeding element 1.

[00028] The backplate element 2 also comprises two bores with internal threads and centering locations 24. The backplate 2 is made of steel or other suitable materials. Screws 15 are arranged in the bore holes of the feeding element 1 and screwed down to the bores 24. Thereby the feeding element 1 is tightly connected to the backplate 2, fixing the carrier element 3 in between. The backplate element is functioning as a back pressure safety device for compensating the feeding pressure of the fluid during the injection.

[00029] A top view of the carrier element 3 can be seen in Figure 2. The carrier element 3 comprises two openings 35, each one connected to one of the microfluidic channels 31. Furthermore, the carrier element 3 comprises two bore holes 34 for the screws 15. In this embodiment of invention the screws 15 are screwed down through the openings 34 of the carrier element 3 into the threaded bores 24 of the backplate 2. The tight and fixed connection will allow to press a fluid through the tube of the feeding element 1 and into the microfluidic channel 31 of the carrier element 3. The feeding pressure is approximately 200 to 400 bar.

[00030] The tight connection between the backplate 2 and feeding element 1 is necessary to prevent the liquid from penetrating the connection between the tube walls 11 and the first layer 32 of the carrier element 3. Thus the screws 15 ensure a tight connection of a macrofluidic channel and a microfluidic channel.

[00031] The carrier element 3 can also be structured in more complex way having different layers and also comprising microfluidic channels, wherein chemical reactions are performed or initialized respectively. However, these channels have to have a microfluidic connection between 5 macrofluidic volumes or channels respectively and their microfluidic volume. A microfluidic connection according to a second embodiment is shown in Figure 3.

[00032] The carrier element comprises two different microfluidic channels 31 and 31A. These two different microfluidic channels 31 and 31A are 10 separated horizontally as seen in Figure 3 as well as vertically by a third layer 37. The different layers are glued or polymerized together respectively in those parts, in which no microfluidic channel is structured. Depending on the materials for the layer used the glues or the polymerization process and methods are different. In this embodiment of the invention the top layer 32, 15 the middle layer 37 as well as the bottom layer 33 all comprise polyimide. This material can be structured in an easy way by an etching method or a laser-induced ablation process to form the microfluidic channels. The material is chemically resistant and neutral for the components to be processed within the microfluidic channels.

20 [00033] In this example the first microfluidic channel 31 comprises an opening in the bottom layer 33 which is connected to a first feeding element 1. The first feeding element 1 connects a macrofluidic volume to the microfluidic channel 31. Opposing the opening of the first microfluidic channel 31 a backplate element 3A is arranged. This element 3A is also 25 part of a second feeding element 1A. This second feeding element 1A connects the second microfluidic channel 31A to a macrofluidic volume. Furthermore a part of the first feeding element 1 also represents the backplate element 3 opposing the second feeding element 1A. Both feeding elements are connected tightly together. Each of the backplate elements 3

and 3A respectively of the feeding elements 1 and 1A compensate the fluid feeding pressure when injecting a fluid through the macrofluidic channels of the feeding elements 1 and 1A into the respective microfluidic channels 31 and 31A. The feeding elements comprise steel or tantalum or similar materials, capable of withstanding high pressures.

[00034] Figure 4 shows another embodiment of the invention comprising a connection between two microfluidic channels. A microfluidic inlet area IA for feeding a fluid into a microfluidic channel 31 is provided. The channel 31 connects the microfluidic inlet area to a macrofluidic outlet area OA. The 10 microfluidic inlet area IA is formed in the same way as the macrofluidic channel of a feeding element. However the dimension of the tube of inlet area IA is significantly smaller than the dimension of a macrofluidic supply area and in the range of the microfluidic channel 31. The carrier element 3 comprising the microfluidic channel 31 is formed by a layer 32 arranged on 15 a structured layer 33. In the areas 39 the two layers 32 and 33 are bonded together. The structured parts are not bonded, thereby forming the microfluidic channel 31. Opposing the feeding elements 1 of the inlet area IA and the outlet area OA backplate elements 2 are arranged, tightly connecting to the respective feeding element and fixing the carrier element 20 3 in between.

[00035] Figure 5 shows a different embodiment of the present invention. The backplate element 2 comprises a recess 25 and two bore holes 24 arranged next to the recess 25. The recess 25 comprises a specific volume and holds an elastic thrust piece 26. The elastic thrust piece 26 is flexible 25 and comprises Teflon or any other material with a resiliency property. The explosive view of the embodiment of the invention according to Figure 5 also shows the carrier element 3, wherein the opening 35 for the microfluidic channel 31 is to be arranged directly above the elastic thrust piece 26. The carrier element 3 is connected to the feeding element 1

comprising a tube 11 connected to the hole 35 of the carrier element 3 and bore holes 14 arranged next to the tube 11.

[00036] The feeding element 1 together with the carrier element 3 is arranged on top of the backplate element 2. The resulting structure is 5 shown in Figure 6. As one can see, the bore holes 14 of the feeding element 1 and the bore holes 24 of the backplate element 2 are filled by screws 15. The backplate element 2 and the feeding element 1 are fixed together by the screws 15 and screw-nuts 16. Providing the elastic thrust piece 26 in the recess 25 of the backplate element 2 allows a more flexible 10 way to compensate for the feeding pressure of the fluid, when feeding the fluid into the microfluidic channel 31. The elastic thrust piece can also be used as protection against overpressure when feeding the fluid into the microfluidic channel. Such an embodiment can be seen in Figure 7.

[00037] The feeding element 1 comprises a second macrofluidic channel 15 having a tube 18, arranged next to the first tube 11. The tube 11 is connected to the hole 35, providing access to the microfluidic channel 31 of the carrier element 3. The second tube 18 is connected to a second opening 39 of the layer 32 of the carrier element 3. The carrier element 3 is structured to form a small volume 40 arranged directly next to the 20 microfluidic channel 31 and the opening 35. However, it is separated by a small wall 98, working as an overpressure valve. The wall is connected to the first layer 32.

[00038] When the feeding pressure into the microfluidic channel 31 exceeds a specific value, the elastic thrust piece 26 is squeezed tightly 25 together, thereby opening a small passage between the bottom of the wall 98 and the bottom layer 33. Fluids can flow to the small volume 40 and to the macrofluidic channel 18. Thereby the feeding pressure of the fluid into the microfluidic channel 31 is reduced and damage prevented.

Figure 9 shows another embodiment of the invention wherein the feeding element 1 is connected to the backplate element 3 by a clamp 4. A top view of the carrier element 3 comprising the microfluidic channel 31 can be seen in Figure 8. The carrier element 3 comprises a spraying nozzle 51  
5 connected to the microfluidic channel 31. The carrier element 3 can be used to spray a fluid into a mass spectrometer. The feeding element 1 comprising the macrofluidic channel is pressed onto the carrier element 3 by the clamp 4. The pressure exceeded by the clamp 4 must be sufficient compared to the feeding pressure when feeding a fluid from the  
10 macrofluidic channel of the feeding element 1 into the microfluidic channel 31 of the carrier element 3.